Radioactive Radiation Source for Ophthalmic Brachytherapy

The present invention relates to a radioactive radiation source for brachytherapy, and especially a radiation source for localized delivery of radiation in surgical procedures, particularly ophthalmic procedures.

Background of the invention

Current therapeutic approaches to ophthalmic diseases, and especially macula degeneration may to a certain extent involve a radiation treatment of the inflicted parts of the macula. More specifically, the current state of the art brachytherapy for treatment of localized lesions, especially tumors and macula degeneration employs radioactive sealed radiation sources. The term "sealed" means that radioisotopes incorporated into a device are integral with the device and cannot be dislodged or released from the host material of the device in the environment of usage. A typical sealed radiation source includes a radiation source encapsulated within an impermeable, biocompatible capsule material, for example titanium, which is designed to prevent any leaching or a release of the radioisotope. The source is typically about 4.5 mm long and has a diameter of about 0.8 mm and is implanted individually at a treatment side within or around a lesion by using hollow delivery needles. These sources suffer from the disadvantage that they provide a homogeneous coaxial radiation pattern over their entire circumference resulting in undesirable irradiation of surrounding healthy tissue.

In the treatment of intraocular tumors in another approach hemispherical ophthalmic plaques are used as sources, incorporating a radioactive material are sewn directly to the eyeball to provide a radiation dose to the intraocular tumor on the concave side of the plaque. These plaques comprise typically a thin film of Ru-106 encapsulated within two sheets of silver, the sheet on the concave side being approximately 0.1 mm thick and the sheet on the convex side being approximately 0.7 mm thick. Accordingly, these sources provide partial shielding of healthy tissue. Greater sheet thickness provides additional ra-

diation shielding but adds to the thickness of the plaque, which increases discomfort to the patient.

In addition, US patent 6 030 333 discloses an implantable radiotherapy device or radiation source for delivering a predetermined dose of radiation in a predetermined pattern, which device includes a biocompatible template and one or more radiation sources which are incorporated directly into at least a portion of the template preferably by ion implantation methods. The emitted radiation pattern and dose is exclusively determined by the pattern of implanting the radiation emitting material into the device or carrier. These devices are disadvantageous in that the radioactive material is irrevocably affixed to the entire device such that finally the entire device needs be deposited after final use thereof.

Other approaches have been used for a non-permanent treatment. For example US patent 6 443 881 discloses a method and an apparatus for use in ocular or ophthalmic brachytherapy. The device comprises a handle, an applicator coupled with said handle, and adapted to receive a source of radiation. The typically concave shaped applicator is movable between a radiation shielding position and a position wherein radiation is allowed to reach the diseased area. A shield receives the applicator so as to shield the radiation source during insertion and positioning proximal to the treatment side. Some sort of shielding may further be provided to prevent emission of radiation in direction towards other tissues than the retina to be treated. In the treatment position, the radiation is directed outwardly through an open area opposing the application site.

A comparable device is disclosed in US-B1-6 285 735. This document discloses an applicator system for applying a dose of x-ray radiation across a predefined contour of a body to treat a predefined volume of tissue. The adapter includes an applicator endcap including a substantially planar or convex treatment surface for engating and conforming a tissue cavity to the desired shape in order to permit the volume of adjacent tissue to be treated with a predefined dose of radiation. The applicator may include a shank having a substantially conical void region to form the punctual radiation beam. The shank may further include an endcap of an appropriate form to facilitate the application of radiation to a surface area and to modulate the emitted radiation uniformly over the surface. The

endcap is preferably formed from a biocompatible acrylic material and fixed to the shank using an epoxy resin. The endcap is directly in contact with the tissue to be treated and is not in contact with the radiation source or probe as defined in the document. Just in contrast, the endcap forms part of the applicator device, not the radiation source itself.

Published US patent application No. US 2002/01 15 902 discloses a surgical device for localized delivery of beta-radiation in surgical procedures, particularly ophthalmic procedures, which device includes a canula with a beta-therapy emitting material at the distal end of the canula. The device may further comprise a shield at the distal end of the canula for shielding the beta-radiotherapy emitting material. This shield at the distal end of the canula may be a thin wall of metal such as stainless steel, or maybe a thin wall of polymer, plastic or similar material. The shield may be retractable to expose the beta-radiotherapy emitting material for treatment. There is, despite of the considerable efforts in the art, no possibility of effectively shielding the surrounding tissue, when homogeneously irradiating the desired site of treatment with a much smaller source.

Summary of the invention

These and other objects can be solved and the drawbacks of the prior art can be overcome by a radioactive radiation source for brachytherapy having an elongated radiation emitting element (1) within an elongated means for containment (2) such that the longitudinal axis of the radiation emitting element and the longitudinal axis of said means for containment are aligned, said means for containment comprising a shielding section (3) and a radiation transition section (4),

- said shielding section (3) covering said radiation emitting element at least partially to substantially attenuate any radiation emitted in the direction of said shielding section,
- said radiation transition section (4) extending substantially along the longitudinal axis of the means for containment and comprising a shielding material (5),
- which shielding material (5) is so adapted as to attenuate the radiation emitted from said radiation emitting element such that, in a plane at a pre-selected distance from the radiation source, a substantially uniform radiation dose is received over a target

area (6) having a length substantially larger than the longitudinal axis of the elongated means for containment, and preferably a diameter substantially larger than the diameter of the means for containment.

The shielding material (5) may be adapted to attenuation of the radiation by varying its thickness, density and/or composition. In general, said shielding material may be adapted by varying its shielding properties.

Other preferred embodiments are as set out in the appending claim.

Description of the Drawings

Fig. 1a and b show an exemplary embodiment of the radioactive radiation source of the invention. In Fig. 1a a longitudinal cross-section is shown, whereas Fig. 1b shows a cross-section along line A-A in Fig. 1a. In this embodiment of Fig. 1 a radiation emitting element (1) is provided in form of a wire. The means for containment (2) integrally comprises a thick shielding section (3) and a radiation transition section (4) on the second halfcircle of the cylindrical means for containment (2). The shielding section (4) comprises the shielding material (5) adapted by varying its thickness. Specifically, the thickness of material (5) is largest in those areas of the means for containment (2) closest to the target area (6), whereas on more laterally and terminally located parts it has a smaller degree of thickness.

Fig. 2a-c show an alternative embodiment of the radioactive radiation source of the invention. Fig. 2a again shows a longitudinal cross-section, whereas Fig. 2b shows the cross-section along line A-A in Fig. 2a. Fig. 2c shows a bottom view of the source after the first capsule (2a) of the means for containment has been peeled off.

Specifically, in this case the means for containment (2) comprises a first capsule (2a) in form of a first sealed metallic cylinder having endplugs. A second metallic cylinder is provided within said first cylinder. The first or upper half circle of the second cylinder within the first cylinder forms a shielding section (3) and the second half circle forms a

radiation transition section (4). The shielding material (5) in the radiation transition section (4) is adapted by varying the wall thickness of the second cylinder. In this embodiment, as can be seen in Fig. 2c 8 recesses (7) are provided parallel to a central bar forming cross bridge (8). The 4 recesses on each side are again separated from each other by bars (8) extending in cirumferrential direction of the second cylinder. Bar (8) is aligned with the central axis of both the first metallic cylinder (2a) and the radiation emitting element (1) within the same. Typically bar (8) is arranged directly opposite the target area (6) such that radiation emitted from the radiation emitting element (1) in a direction normal to the target area will be more strongly attenuated as compared to radiation emitted in a slightly tilted direction through the recesses (7). Thereby, a homogenous radiation can be achieved.

Figures 3a-c show a practical embodiment for the shielding section (3) and the transition section (4) of a radiation source of the invention.

Fig. 4 provides for a dosis rate profile at the radiation transition side (4) of the source of Fig. 3.

Fig. 5 provides for a dose rate profile at the retina side or shielding section (3) of the source of Fig. 3.

Detailed Description of the Invention

The radioactive radiation source of the invention is suitable for brachytherapy and especially for ocular or ophthalmic brachytherapy such as in the treatment of macula degeneration, preferably age related macula degeneration (AMD). The radiation source of the invention comprises a radiation source for brachytherapy having an elongated radiation emitting element (1) within an elongated means for containment (2) preferably arranged such that the longitudinal axis of the radiation emitting element and the longitudinal axis of said means for containment are aligned. Said means for containment comprises a shielding section (3) and a radiation transition section (4). Said shielding section (3) covers said radiation emitting element at least partially to substantially attenuate any radiation emitted

in the direction of said shielding section. Preferably the shielding section covers the element to about 30-90 %, preferably 40-70 % and more preferably 50-60 %.

Said radiation transition section (4) extends substantially along the longitudinal axis of the means for containment and comprises a shielding material (5), which shielding material (5) is so adapted as to attenuate the radiation emitted from said radiation emitting element such that, in a plane at a pre-selected distance from the radiation source, a substantially uniform radiation dose (deviations less than 30 %, preferably less than 20 %, more preferably less than 10 %) is received over a target area (6) having a length substantially larger than the longitudinal axis of the elongated means for containment, and, preferably a diameter substantially larger than the diameter of the means for containment. The term "substantially" as used in this context generally means at least 50 % enlargement preferably 100 to 200 % enlargement in the intended dimension.

As used herein the term "elongated" means any shape of the radiation emitting element having one axis substantially larger than the other two axes. Preferably the aspect ratio of the elongated radiation emitting element (ratio of longitudinal axis to diameter) is $\geq$ 2:1, more preferably 5:1 to 25:1 and most preferably 8:1 to 17:1, especially 10:1. In general, the radiation emitting element may have any cross section, provided this cross section does not prevent its movement within a catheter or any other delivery device. Preferably, the cross section is circular, ellipsoid or polyhedric, circular cross-sections being preferred. In case of non-circular cross-sections the above aspect ratio is determined using the largest diameter in a plane perpendicular to the longitudinal axis.

The radiation emitting element may generally adopt any suitable form, as long as the form is elongated and does not interfere with its intended purpose. Typically it will be a single solid or hollow body, but may also be composed of several individual elements arranged in series within the means for containment to form the elongated shape of the element. The element preferably is a single body, which may itself be hollow or solid. More preferably the radiation emitting element is a cylindrical wire, optionally wound in form of a coil, or a tube. Alternatively, if consisting of several elements, these may be spheres or ellipsoids arranged in series.

The elongated radiation emitting element is sealingly enclosed within the means for containment. This means for containment (2) has an elongated shape, its longitudinal axis being typically being aligned with and preferably being arranged in parallel to the longitudinal axis of the radiation emitting element. An arrangement "in parallel" as referred to herein does not exclude a slight tilting of the respective longitudinal axes towards each other e. g. up to 20°, preferably to 10°. This is as long as the elongation is substantially within the same direction. Preferably the means for containment in its dimensions matches the outer dimensions of the elongated radiation emitting element, such that the latter tightly fits within the means for containment.

The outer dimensions of the means for containment or cover sleeve, where applicable, will typically define the dimensions of the radioactive radiation source as well. The radiation source itself may generally have any length as considered appropriate by the skilled worker for the chosen side of treatment. Typically it will have a length in the range of ≤1 to 25 mm, preferably 1 to 15 mm, more preferably 2 to 10 mm and most preferably 2 to 5 mm. Likewise, the radiation source will typically have a diameter in the range of 0.1 to 2.0 mm, preferably 0.6 to 1.2 mm, most preferably 0.8 to 1.2 mm.

The radiation emitting element (1) typically has a compatible outer diameter in the range of 0.1 to 1 mm, preferably 0.2 to 0.8 mm. More preferably the radiation emitting element has an outer diameter in the range of 0.1 to 0.5 mm and most preferably 0.3 to 0.4 mm. The inner diameter of the means for containment (2) is chosen appropriately to receive the element (1) therein. The above-referenced dimension of the radiation source of the invention typically relate to the means for containment thereof. The radiation source of the invention may, however, also be affixed to a catheter or an applicator of appropriate length for advancing the radiation source to the desired site of treatment. Similarly the source may be brought in position by using an applicator or a catheter using the conventional after-loading technology. In a preferred embodiment the means for containment forms an integral part of the catheter/applicator at its tip as is e. g. disclosed in US laid open publiction 2002/0115902 and the radiation emitting element is fixed therein.

In an alternative embodiment the shielding section and the radiation transition section may, optionally together with a cover sleeve, be inbuilt and integral to the applicator tip. A conventional seed including a radiation emitting element sealingly enclosed in a capsule may then be moved by afterloading into the tip of the applicator to form the final radiation source of the invention.

The means for containment may in addition to the elongated radiation emitting element also include a radioopaque marker to allow monitoring of the advance of the radiation source in use. Such radioopaque marker may be provided in the central core within a hollow coil-shaped or hollow cylindrical radiation emitting element, and/or may be provided as separate body on one or both sides of the radiation emitting element or interspersed between e. g. several spheres, forming said radiation emitting element. Other embodiments of including a radioopaque marker within the means for containment comprising the radiation emitting element are well known to the skilled worker. These are encompassed by the present invention.

The means for containment comprises a shielding section (3) and a radiation transition section (4). These two sections may together form the means for containment or sections thereof or may be provided as separate and distinct sections on the inside or outside of a first layer or capsule (2a), which layer or capsule sealingly encloses the radiation emitting element to provide the containment function. As an example, the first capsule (2a) may be formed in form of a hollow cylinder having endplugs, which capsule sealingly encloses the radiation emitting element. Within or around, but preferably within capsule (2a) there can be provided a second cylinder comprising and/or forming the shielding section (3) and the radiation transition section (4) the latter being e. g. provided by varying wall thickness of the second cylinder on one side thereof. Providing these sections within the first capsule has the advantage that any sharp edges on the outer side of the source can be prevented which may cause injuries during insertion or removal. Alternatively a cover sleeve may be provided as discussed below.

In another embodiment the shielding section (3) and the radiation transition section (4) are integral parts of the means for containment (2). Again the radiation transition section (4)

may be provided e. g. by varying and especially decreasing the wall thickness of the means for containment in a pre-determined section thereof.

The shielding section (3) covers the radiation emitting element at least partially to substantially attenuate any radiation emitted in the direction of said shielding section. As used herein the term "substantially attenuate" means attenuation of radiation in the shielded direction to desirably low levels to prevent damage of surrounding tissue at the site to be treated and preventing undesired exposure of medical personal. Specifically, attenuation is preferably achieved to decrease the radiation by more than 90 %, preferably more than 99 % and most preferably 100 % of the emitted radiation in said direction.

The radiation transition section (4) forms a second part of the means for containment (2). This section extends substantially along the longitudinal axis of the means for containment. With the term "extending substantially along" as used herein it is meant that the radiation transition section is aligned over the longitudinal axis of the means for containment, preferably aligned centrally over the longitudinal axis of the means for containment and corresponds in its length at least to a larger portion of the length of said longitudinal axis of the radiation emitting element comprised within the means for containment and preferably of the means for containment itself. Typically, the radiation transition section will extend itself over and along of more than 50 % of the longitudinal axis of the means for containment, more preferably 60 to 100 % thereof and most preferably 75 to 95 % thereof.

The radiation transition section (4) is located on the side or face of the radiation source of the invention (its means for containment) opposing or intended to oppose the target area to be irradiated.

The radiation transition section (4) comprises a shielding material (5). This shielding material (5) is so adapted as to attenuate the radiation emitted from the radiation emitting element in such a manner that, in a plane at a preselected distance from the radiation source, a substantially uniform radiation dose is received over a target area (6), having a diameter substantially larger than the diameter of the means for containment and a length substantially larger than the longitudinal axis of the elongated means for containment.

Adaption of the shielding material (5) occurs by adapting its shielding properties. This may be achieved through varying its thickness, density and/or composition. In a preferred embodiment the shielding material (5) is adapted by varying its thickness. In this embodiment the adaption may specifically be achieved by providing the shielding material in a greater thickness on such portions of the radiation transition section (4) closer to the target area (6), than on those further away from the same.

Taking into account that the emitted radioactive radiation suitable for brachytherapy is effectively shielded even in air, let alone a body fluid or tissue, any travel distance of the radiation beam through (i) means of containment, (ii) fluid or air, and (iii) tissue will effectively decrease the radiation dose received in the preselected target area. Any radiation emitted in a direction normal to the plane of the target area (i. e. on the part of the source closest thereto) will have to travel the shortest distance and will thus experience the least attenuation. Any radiation emitted in a direction tilted with regard to the normal direction will travel longer and will thus experience a higher degree of attenuation, the degree of attenuation depending on the travel distance and hence the angle of tilting as well as the medium through which the radiation passes.

To allow for homogeneous radiation doses being achieved in a target area larger than the dimensions of the source itself, radiation emitted in tilted directions need to be used as well. These are, however, prone to deliver a smaller radiation dose at the target area. The present invention provides the shielding material to modulate (by appropriate attenuation of) the emitted radiation especially the radiation emitted in normal direction, to cope with this difference and to finally achieve a homogeneous radiation dose in the preselected target area. Thereby very small radiation sources can be used to effectively and homogeneously irradiate a larger target area.

In an especially preferred embodiment the shielding section (3) may cover the radiation emitting element (1) over the full length of its longitudinal axis on at least one side of the element. Accordingly, substantial emission of radiation to this side of the radiation source

can be prevented. The radiation transition section (4) is then preferably located on the side of the radiation emitting element opposite to the shielding section (3).

In a preferred embodiment the shielding material (5) may advantageously be provided with higher shielding capacity (e. g. in a greater thickness) centrally over and along the longitudinal axis of the radiation emitting element on that part closest to the target area. Besides this central part a shielding material of lower shielding capacity (e. g. of smaller thickness) is provided. This can be either throughout the full length of the central part or throughout a partial length thereof. Preferably, the shielding material of smaller thickness is provided on both sides of the central part either over the full length of the same or towards the ends of the radiation emitting element, leaving an area of higher shielding capacity (e. g. larger thickness) towards the central part of the radiation emitting element.

The most preferred embodiment, the shielding material (5) may comprise recesses (7), in particular recessed windows (no shielding material), on such portions of the radiation transition section (4) further away from the target area (6). The shielding material (5) is in this case again provided centrally over or along the longitudinal axis of the radiation emitting element, the one or more recesses being provided on either or both sides thereof. Preferably arrangement of more than one (2-10, preferably 4-8) recesses is symmetrical to the central axis of shielding material (5).

The shielding material (5) may also be adapted by varying its shielding effect through varying its density and/or composition. In this case a material with a high shielding effect may be used on such portions of the radiation transition section (4) closer to the target area (6), while on such portions of the radiation transition section (4) further from the target area (6) a material with a lower shielding effect may be used. The composition of the shielding material may e. g. be changed throughout the shielding material by techniques such as iron bombardment, sputtering and so on.

More specifically, in case of a metallic shielding material, its composition may be changed by iron bombardment with a heavier metallic material to achieve the desired change in composition. For example the more transmitting sections of the radiation transmitting

section (4) may be masked during iron bombardment and all other parts may be bombarded with a heavier material to increase their attenuation factor to the desired extent.

In a preferred embodiment, the shielding material (5) of the radiation transition action (4) is so adapted that the radiation emitted through said radiation transition section (4) is incident on a target area of substantially planar circular form to provide a substantially uniform radiation dose in said plane.

According the embodiment shown in Fig. 1 the shielding section (3) and the radiation transition section (4) form integral parts of the means for containment (2).

Alternatively, as shown in Fig. 2 the means for containment (2) may comprise a first layer or capsule (2a), which layer or capsule sealingly encloses the radiation emitting element (1) and further comprises a shielding section (3) and a radiation transition section (4), which are provided separately from the first layer or capsule (2a) on the outside (not shown) or inside thereof. Preferably, the shielding section and the radiation section are provided on the inside of the layer or capsule (2a) as shown in Fig. 2. In this for example, the means for containment (2) comprises a first capsule (2a) in cylindrical form, which capsule is provided with endcaps to sealingly enclose the radiation emitting element (1). The shielding section (3) and the radiation transition section (4) may then be provided in form of a second cylinder. The radiation transition section (4) is provided on the second cylinder by appropriately adapting the wall thickness of the second cylinder in one halfcircle thereof or by changing its composition through iron bombardment in appropriate manner as disclosed above. The second cylinder may preferably be affixed to the first capsule by any appropriate means, e. g. by welding or use of an adhesive.

The emitting element according to the present invention may comprise any appropriate radioactive radiation emitting nuclide as known suitable for medical purposes. IN one preferred embodiment the radiation emitting element is a β-radiation emitting element. Preferably nuclides are chosen having a maximum particle energy of β-radiation of at least 500 keV and preferably no photon energy for γ-radiation, if possible. Alternatively x-ray or soft γ emitting nuclides with photon energies between 20 keV and 200 keV, more

preferably 20 keV and 100 keV may be used. These radioactive materials are soft emitters which are most desirably used in treatment of biological materials and tissue, due to their short attenuation distance. β-source electrons of these energies typically only penetrate only 1 to 10 mm into human tissues. They are easily shielded by even plastic materials. Accordingly, the damage to neighbouring tissues surrounding the site to be treated can be minimized.

In a preferred embodiment the radiation emitting element comprises a nuclide selected from the group consisting of Y-90, Sr-90/Y-90, Tm-170, P-32, Cl-36, Ce-144, Pr-144, Tb-160, Ta-182, Tl-204, Sn-123, Re-188, Ir-192 and Se-75. Most preferably, the radiation emitting element comprises one of the nuclides Y-90, Tl-204, P-32 or Tm-170. The nuclide can be supported on a non-radioactive support or can be comprised in a metallic, plastic or ceramic matrix. Mixtures of these materials may also be used. Preferred are embodiments, wherein the nuclide is embedded in a matrix, most preferably metallic matrices are used. In these the nuclide may be embodied in elemental form i.e. to yield an alloy or in form of a compound such as an oxide, halogenide or carbide, nitride and so on. Corresponding suitable radiation emitting elements are e.g. disclosed in European patent application EP-A-1 084 733, the content of which is incorporated herein by way of reference.

The shielding section (3) may comprise and preferably consist of a metallic, ceramic or plastic material, preferably a metallic material; most preferably a metallic material selected from high atomic number metals. Preferably these metals are selected from the group consisting of Pt, Pd, Au, Ag, Ir, Pb, W and their alloys, compounds, and composites and mixtures thereof. Especially, carbides and nitrides and composite materials of the same can be used.

The means for containment (2, 2a) may comprise and preferably consist of a metallic, ceramic or plastic material. In case of metallic materials these are preferably selected from the group consisting of Al, Ag, Au, Pb, Cd, Ce, Cr, Co, Cu, Fe (especially stainless steel), Hg, Hf, Bi, In, Mg, Mn, Mo, Nb, Ni, Pd, Pt, Pr, Re, Rh, Sn, Si, Ta, Ti, Tb, Th, V, W, Y, Yb, Zn, Zr and their alloys, compounds, and composites and mixtures thereof. Carbides and nitrides of these materials may be used. Preferred are biocompatible materials such as

Ti and its alloys. In case the shielding section forms an integral part of the means of containment, both are preferably made from the same material. In this case high atomic number metals as listed above are typically used.

The means for containment is preferably provided in a tubular or cylindrical form. For a sealing enclosure of the radiation emitting element this tubular or cylindrical form may be provided with endcaps or endplugs on both sides thereof. Similarly the radiation emitting element (1) according to the invention may be provided in tubular or cylindrical form (hollow and solid), preferably with a diameter such as to closely fit into the internal diameter of the means for containment. The radiation emitting element may, however, also be comprised of one or more spherical elements (1a). these are typically spheres of a diameter closely matching the internal diameter of the means for containment, although smaller spheres may likewise be used.

The radiation source of the present invention may further comprise a cover sleeve provided around the means for containment. Said cover sleeve may, but needs not sealingly enclose the means for containment, though a sealing enclosure is preferred. As an example, the cover sleeve may be provided in form of a (third) cylinder around the means for containment.

The cover sleeve is made of any appropriate radiation resistant, non-corrosive, biocompatible material. Preferably it consists of any of the metallic materials listed above for the means for containment, Ti, Al, Ni, Fe (stainless steel) and their alloys being especially preferred.

Providing the cover sleeve around the means for containment bears the advantage that (1) any high Z materials which need not be biocompatible can be prevented from leaching into the body, (2) any edges of the means for containment are covered to prevent damages to surrounding tissue upon insertion and removal, and (3) the source can be easily cleaned and sterilized for re-use.

Like the means for containment, the cover sleeve may also be attached to or from part of the applicator tip, e. g. as a hollow cylindrical extension thereof, receiving the means for containment which is sealed therein by an endplug. Endplugs are preferably attached by laser welding.

By providing the means for containment of the radiation source of the present invention with a radiation shielding section (3) and a radiation transition section (4), the radiation source of the present invention allows, differing from prior art radiation sources, which typically show axially homogenous radiation patterns (i.e. a pattern of homogenous irradiation around its circumference), an intentionally inhomogeneous radiation pattern. More precisely, the emitted radiation is shielded at least on one and preferably to but one side of source. Accordingly, undue radiation of healthy tissue opposing and surrounding the site to be treated can be prevented as the emitted radiation is directed appropriately. This is especially important in ophthalmic applications such as irradiation of the macula in case of macula degeneration. In these cases the radiation source needs to be placed in between macula and retina, irradiation of the retina being highly undesirably.

The radiation source of the present invention allows the precise irradiation of the involved spot of the macula without irradiating the retina in parallel. Further, by an appropriate adaption of the radiation transition area (4) the source of the present invention allows a substantial homogenous irradiation of the macular part to be treated. In addition, this part to be treated can be substantial larger than the diameter and length of the radiation source itself. Accordingly, smaller sources can be used for treating larger patches of macula, which advantageously reduces the size of inscissions and invasions needed for a successful treatment. This in turn of course reduces risks incurred by the patient during the treatment/surgery.

The present invention will be illustrated by the following example, which is not intended to limit the same.

Examples

Example 1

A radiation source was manufactured by providing a wire, comprising an oxide of yttrium-90 dispersed within a metallic matrix, in this case an aluminum matrix. The wire was inserted in a first metallic cylinder, sealed by endpugs, as the means for containment. The first metallic cylinder was made of stainless steel, the endplugs being made from the same material. The first sealed metallic cylinder was inserted in a second cylinder made from an Pt/Ir-alloy, which second cylinder was provided around said first cylinder with closely matching dimensions to firmly hold said first sealed cylinder.

The first halfcircle of said second cylinder around the means for containment and aligned with the cylinder axis thereof forms the shielding section. The second halfcircle around the means for containment and aligned with the cylinder axis thereof forms the radiation transition section by varying the thickness of the Pt/Ir-alloy along the length of the second cylinder.

Eight recesses (7) are provided in a regular pattern along a central crossbridge along the longitudinal axis of the second cylinder. These recesses form windows, i. e. openings allowing access to the first cylinder below.

The source of this example further comprises a cover sleeve in form of an end plugged, thin-walled, third cylinder provided around the second cylinder to receive and hold the same. The cover sleeve is made from Ti or a Ti-alloy. It seals the radiation source and provides a cover for any edges of the second cylinder. All cylinders are affixed to each other and/or sealed by laser welding.

The emitted radiation field of the source was tested in a target area of about 4-6 mm diameter at a distance of about 1-2 mm from the source surface. The field was homogeneous within limits of about 30 % variation in dose from center to fringe. In comparison, a source not having a transition section according to the invention showed deviations of more than 50 % from center to fringe.

Example 2

Similar to example 1 a radiation emitting element within a means for containment and a second cylinder is provided, made from the same materials. In this case, however, the second cylinder had the shape and construction as shown in Fig. 3a-c.

Specifically, Fig. 3a shows a perspective view of a hollow cylindrical body with a slanted distal end portion (9), the outermost edge (10) thereof being chamfered. Four recesses (7) are separated by central bars (8) having an enlarged cross-section (11). The radiation shielding section (3) is provided on the opposite side of the tube, in alignment with the proximal edge of the slated end. The radiation transition section (4) is in alignment with and on the side of the distal / outermost edge of the slanted end of the entire tube.

Fig. 3b shows a bottom view of the source of Fig. 3a. It is apparent that in this case, longitudinal bar (8a) is aligned with the longitudinal axis of the entire cylinder and is also aligned with the middle portion of chamfered edge (10). Recesses (7) are provided as windows formed by removing part of the cylinder wall of the first capsule (2a) to allow access to the tubular internal volume, which is to receive the radiation emitting element, sealed within a tubular / cylindrical means for containment. Windows (7) are preferably provided with rounded corners, especially on those parts surrounded and formed by bars (8).

Fig. 3c is a cross-section along line A-A in Fig. 3b. Fig. 3c shows the distal slanted end (9) and chamfered edge (10) made from the cylinder material. On the bottom side recesses (7) are shown from the inside of the cylinder, which are separated by cross-bar (8b). The windows (7) are likewise provided with slanted corners, and extend here nearly over the lower half circle of cylinder (2a). The proximal end of the cylinder is open for attachment to a catheter. The end portion (12) is tapered at constant outer diameter.

Fig. 4 and 5 show dose rates obtained with this source over the shielding section (3) and the transition (4) section, respectively.

Fig. 4 shows a high level radiation plateau of 11 Gy/min for about 1 mm around the centre of the source, corresponding to the site of treatment. Fig. 5 shows two peaks of much smaller radiation doses towards the sides of the source (~ 1.2 Gy/min), which quickly level of both towards the center, where full shielding occurs, and towards the sides.

Although having been described with respect to preferred embodiment as set out above, this description is not to be considered limiting in that the skilled worker will appreciate the possibility of several variations of the invention as defined in the appending claims without departing from its scope.